The sPHENIX Project

Rutgers Collaboration Meeting
Piscataway, NJ
Dec 10-12, 2015

Excerpt from the Executive Summary Cost and Schedule Review Report

"There are many exciting challenges ahead for sPHENIX. A new collaboration is under development, with the first collaboration meeting planned for December 2015. We believe that a highly engaged and robust scientific collaboration is a vital component of the sPHENIX project and physics program, and that all effort should be made to develop this collaboration, and its integration with the PHENIX project, as quickly as possible."

- sPHENIX Cost and Schedule review committee

The sPHENIX Project

The PHENIX Experiment is about to start its 16th and final year of operation.

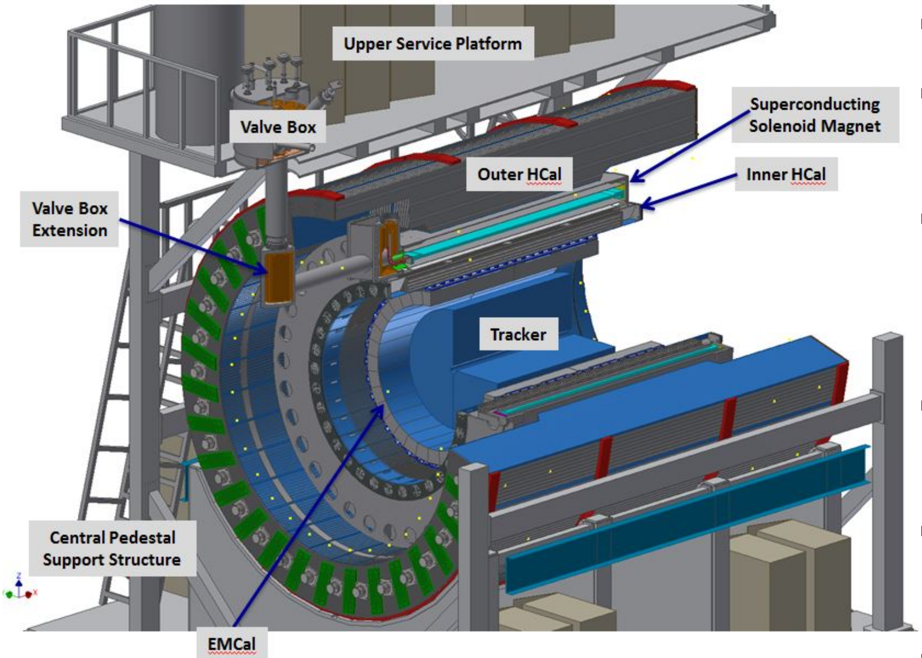
The majority of the equipment was designed and built in the mid-1990's

Particular physics results from both LHC and RHIC call for measurement capabilities that are beyond those available at either PHENIX or STAR

A proposal has been submitted to DOE to build a mid-size detector with the following features:

- High rate, relatively unbiased trigger
- Strong magnetic field: SC magnet
- 2π calorimetry coverage, both EMCal and HCal
- Modern technology but nothing that requires long lead time development
- Reuse of most infrastructure in the **1008 complex** including the DAQ and computing (with modest updating)
- Build to a schedule that would allow the first sPHENIX run in early 2021
  - Based on review committee recommendations and advice from BNL this will now be changed to early 2022.
- Potential future application as a foundation for an EIC detector

sPHENIX Reference Design



- Uniform acceptance $|\eta| < 1.1$ and $\phi = 2\pi$
- Use of BaBar solenoid now at BNL
- Hadronic calorimeter doubling as flux return
- Compact electromagnetic calorimeter to allowing fine segmentation at a small radius
- Solid state photodetectors that work in a magnetic field, have low cost, do not require high voltage
- Common readout electronics in the calorimeters
- High rate 15+ kHz in AA allows for large unbiased MB data sample
- Potential re-use of PHENIX silicon vertex detector plus additional silicon tracking layers.

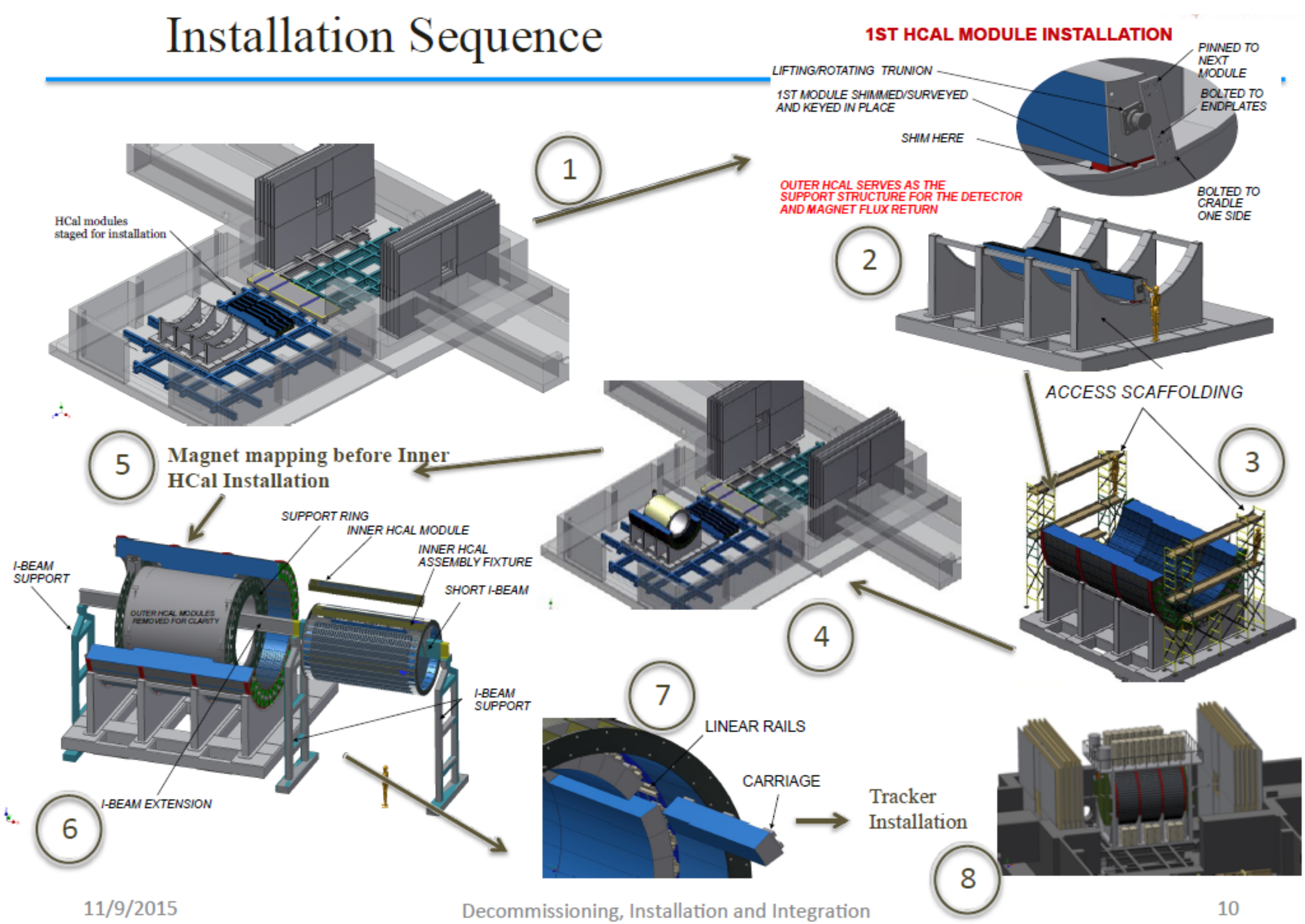
We are striving to keep the sPHENIX design as straight-forward and low cost as practical

Recent sPHENIX Calendar

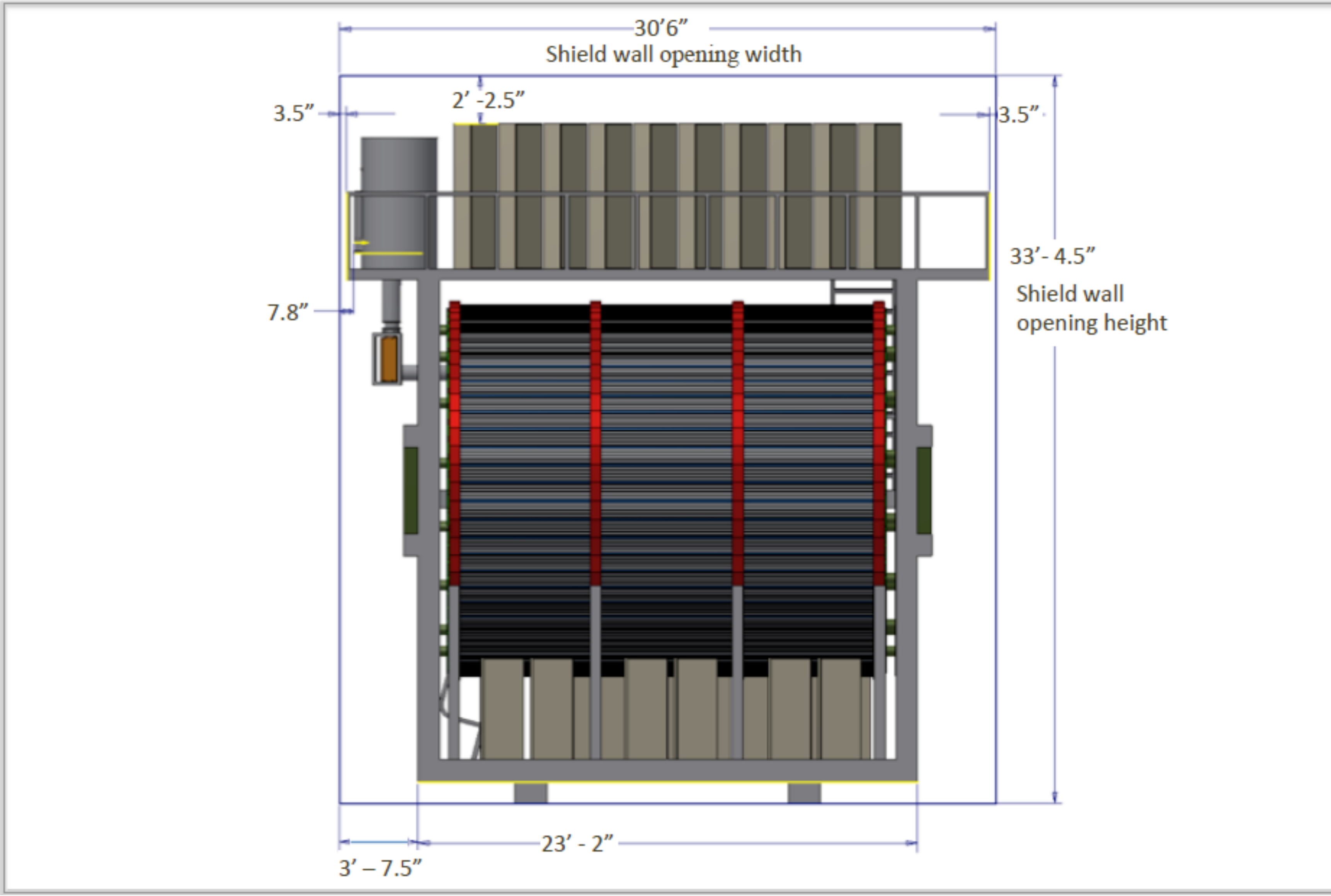
• sPHENIX Proposal submitted to DOE	Fall 2012
• DOE Science Review	July 2014
• Internal Rev of SC-magnet	Dec 2014
• Internal Rev of Decommissioning and Installation	Jan 2015
• Internal Rev of HCal	Feb 2015
• BaBar magnet arrives at BNL	Feb 2015
• Internal Rev of Calorimeter Electronics	Mar 2015
• DOE Science Review	April 2015
• New RHIC Collaboration formation Workshop	Jun 2015
• Internal Rev of EMCal	Aug 2015
• NPP Director's Cost and Schedule Rev	Nov 2015
• 1st Meeting of new "sPHENIX" Collaboration	Dec 2015

Many internal reviews and a successful DOE Science Review

Mechanical Design

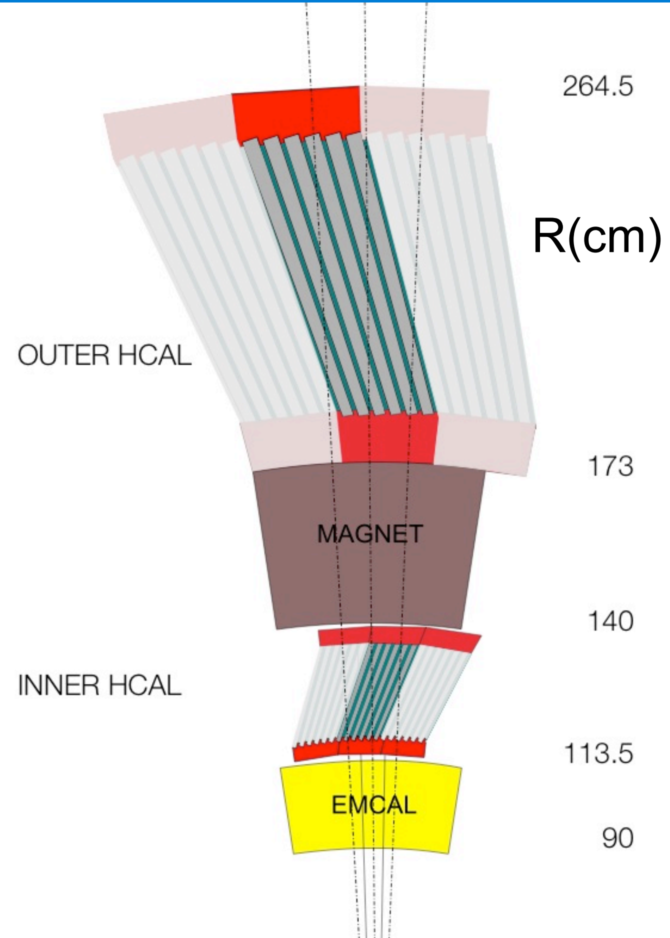


Overall Detector Size and Shield Wall Opening



Calorimeter reference design

- **EMCAL** Tungsten-scintillating fiber
  - $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$
  - 96 x 256 readout channels
  - EMCal $\Delta E/E < 15\%/\sqrt{E}$ (single particle)
- **HCAL** Steel and scintillating tiles with wavelength shifting fiber
  - 2 Longitudinal segments.
  - An Inner HCal inside the solenoid.
  - An Outer HCal outside the solenoid.
  - $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
  - 2 x 24 x 64 readout channels
  - HCal $\Delta E/E < 100\%/\sqrt{E}$ (single particle)
- **Readout** Solid state photodetectors (silicon photomultipliers, avalanche photodiodes)

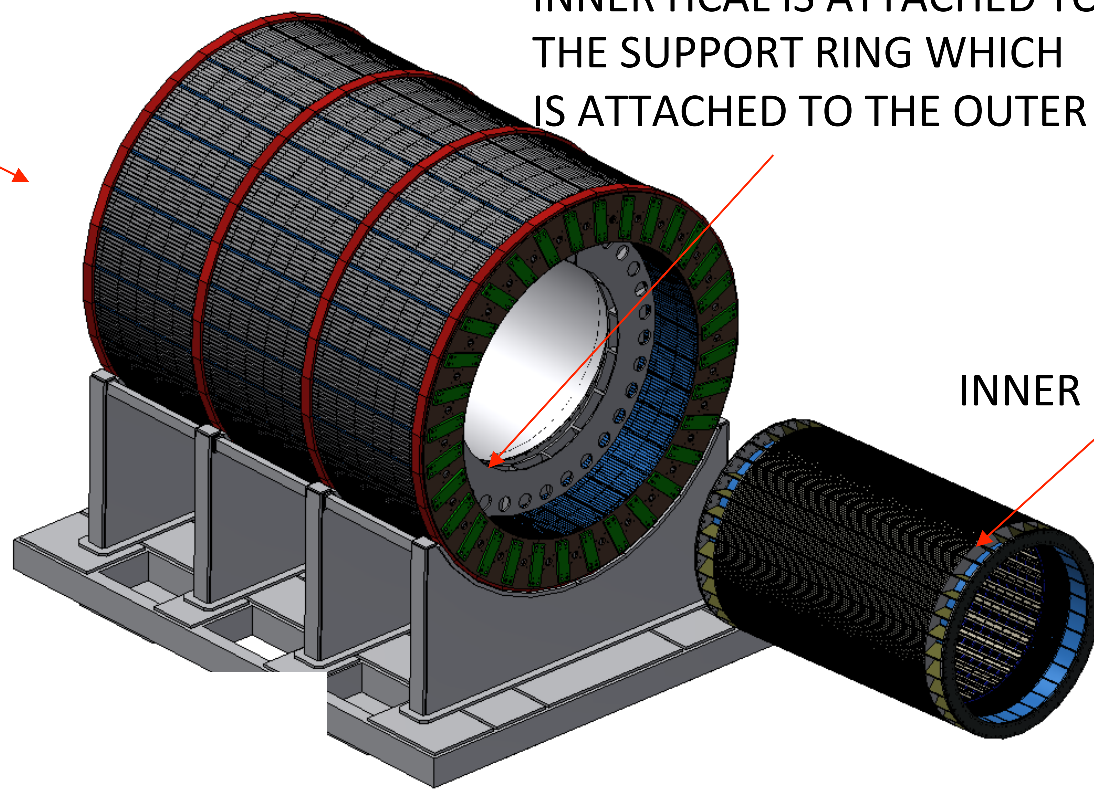


- Outer HCAL $\approx 4\lambda_I$
- Magnet $\approx 1X_0$
- Inner HCAL $\approx 1\lambda_I$
- EMCAL $\approx 18X_0 \approx 1\lambda_I$

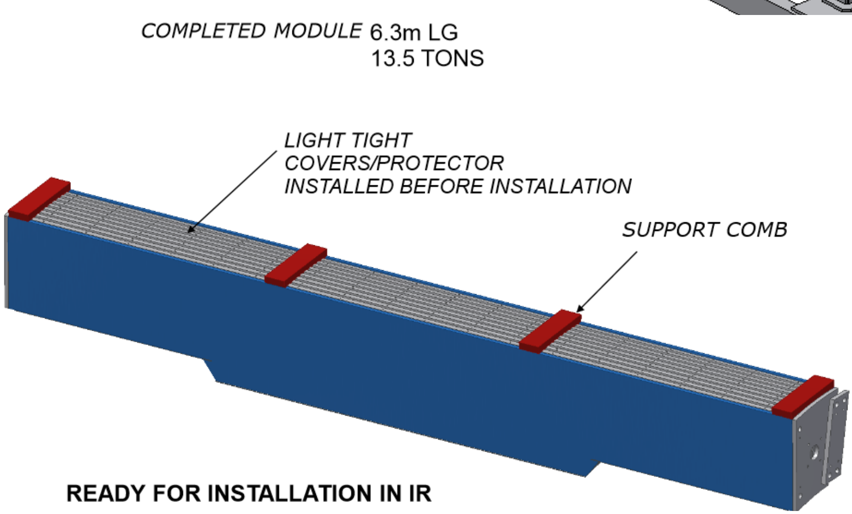
Structure and Integration of HCal

OUTER HCAL

INNER HCAL IS ATTACHED TO
THE SUPPORT RING WHICH
IS ATTACHED TO THE OUTER HCAL.



INNER HCAL



OUTER HCAL MODULE

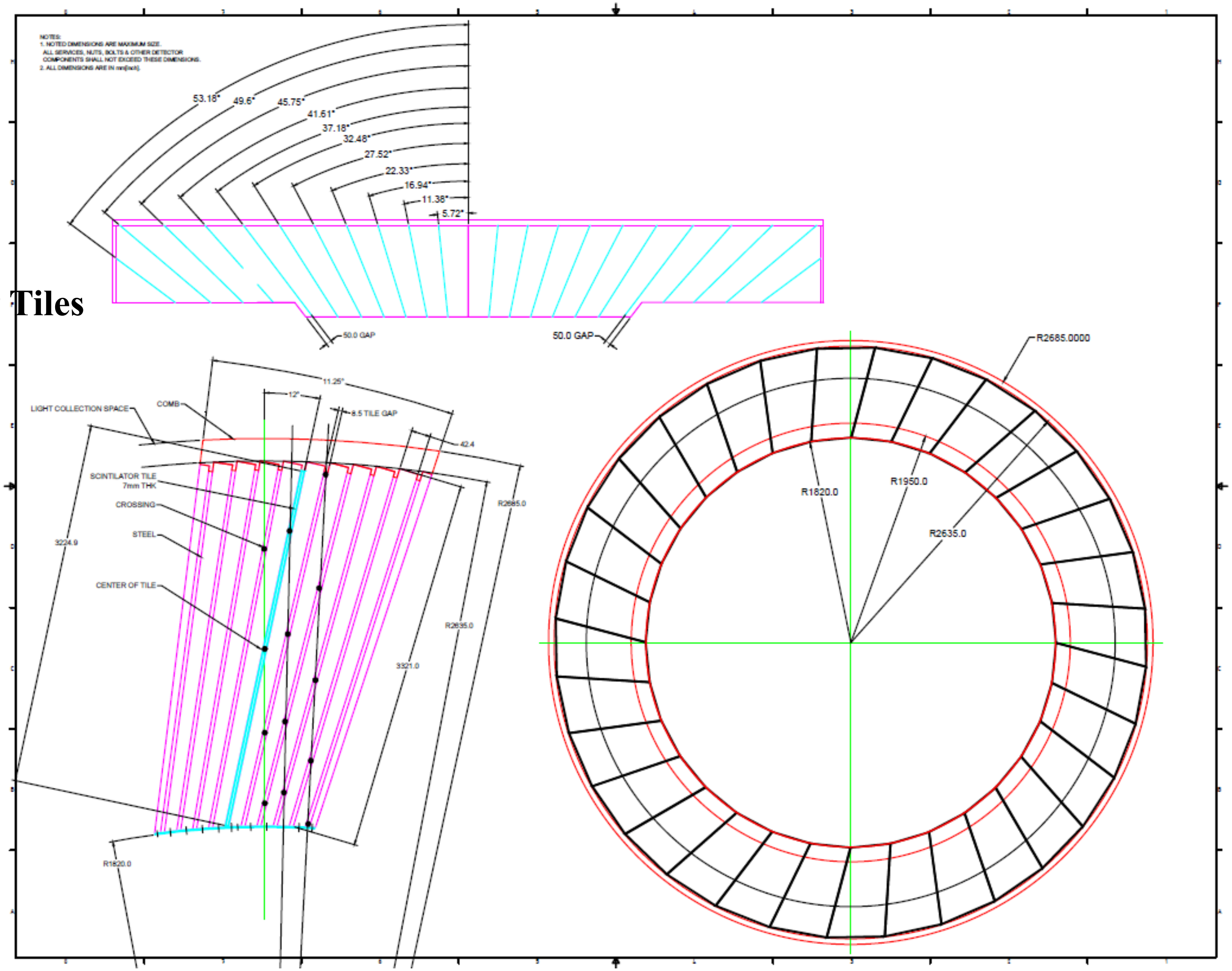
Outer HCal Reference Design

32 MODULES

INNER R= 1.9m
OUTER R= 2.6m

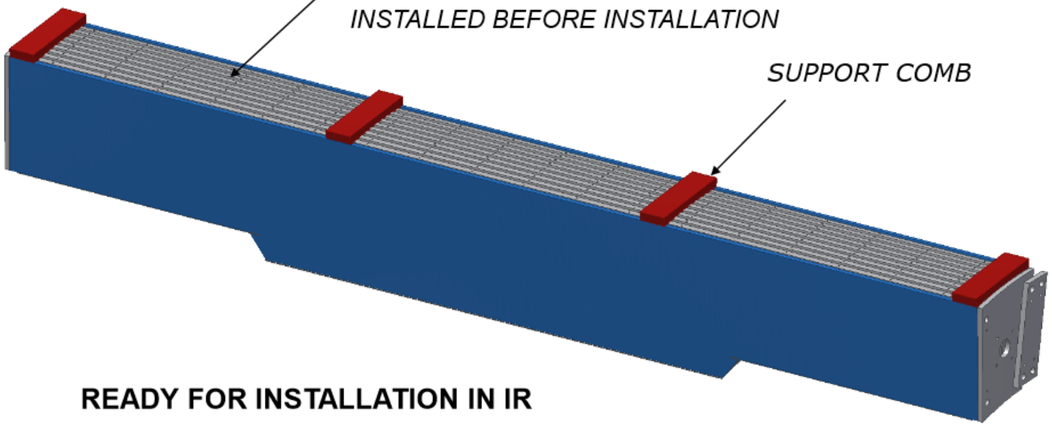
10 Rows: 7mm Scint Tiles
22 Tiles/ row

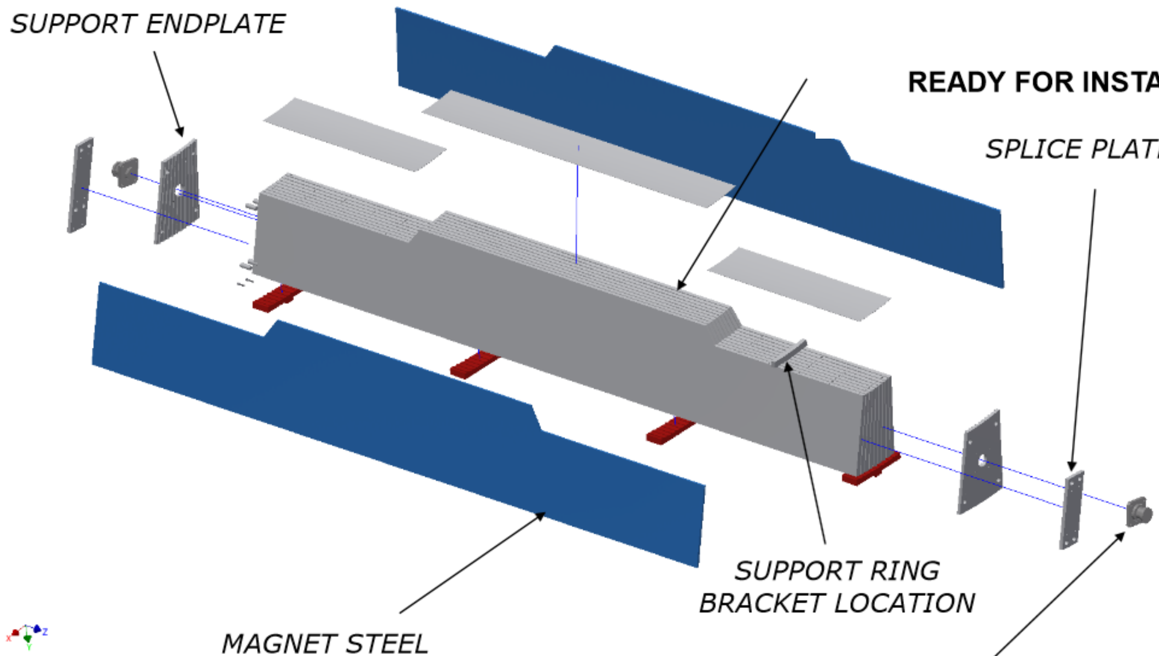
Absorber:
Tapered 1006
Steel Plates
w/thickness
Rin= 26.1mm
Rout= 42.4mm



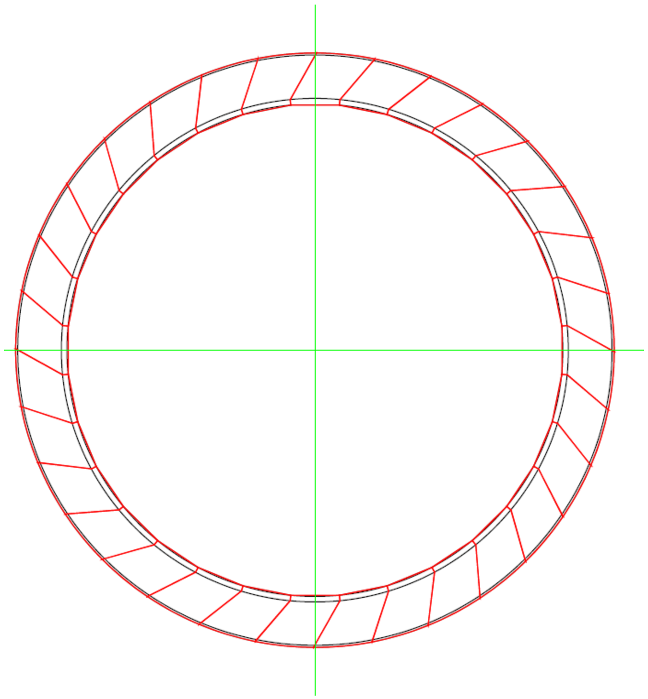
Outer HCal Reference Design

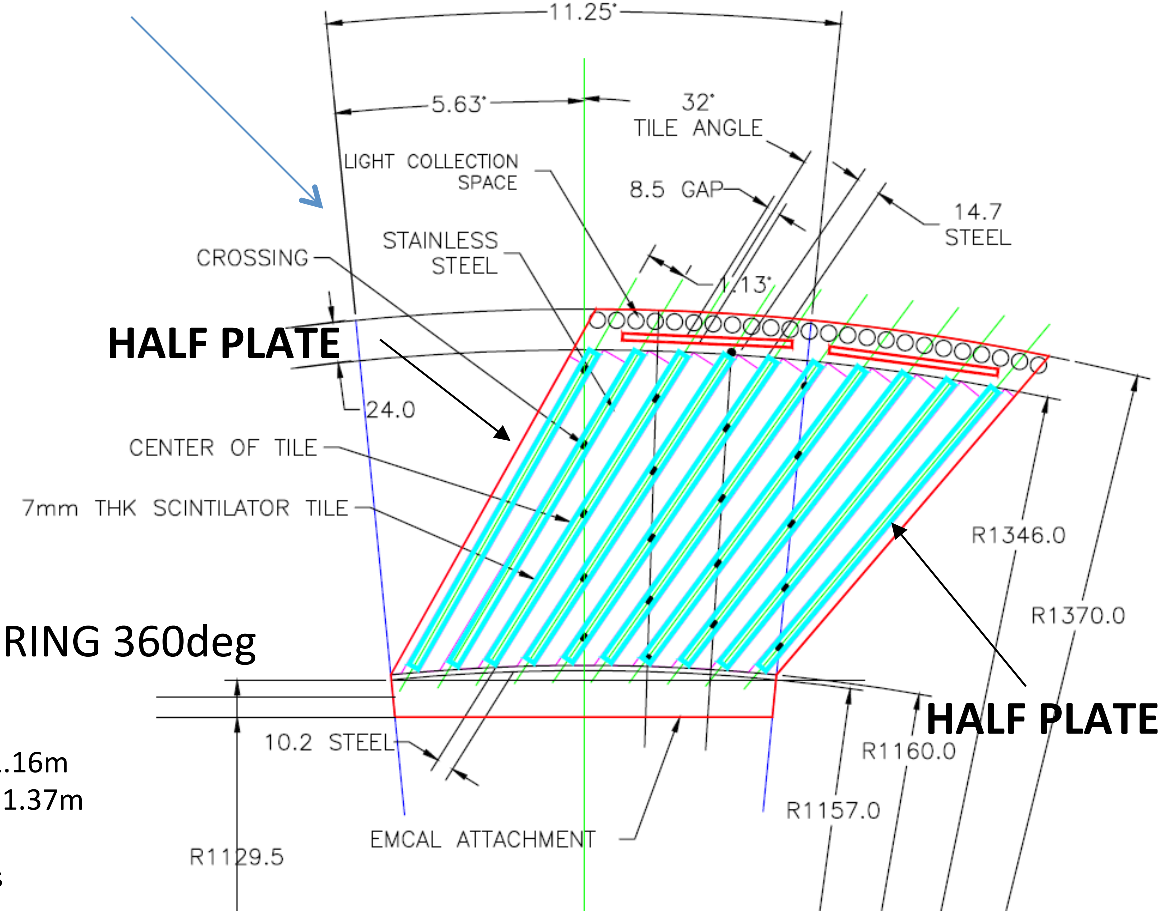
Detailing near complete for full scale HCal Prototype. We plan to build one in the next 12 months.





Inner HCal Reference Design



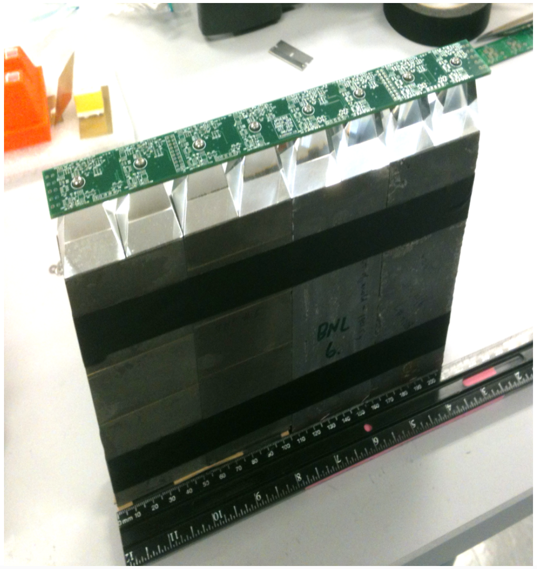


32 MODULES COVERING 360deg

INNER RADIUS ENVELOPE -1.16m
OUTER RADIUS ENVELOPE - 1.37m

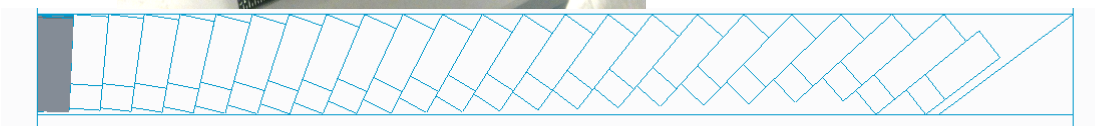
10 ROWS of 7mm Scint Tiles
22 Tiles in each row.
32deg Tilt Angle
~10.2mm – ~14.7mm Tapered SST 304 Plates

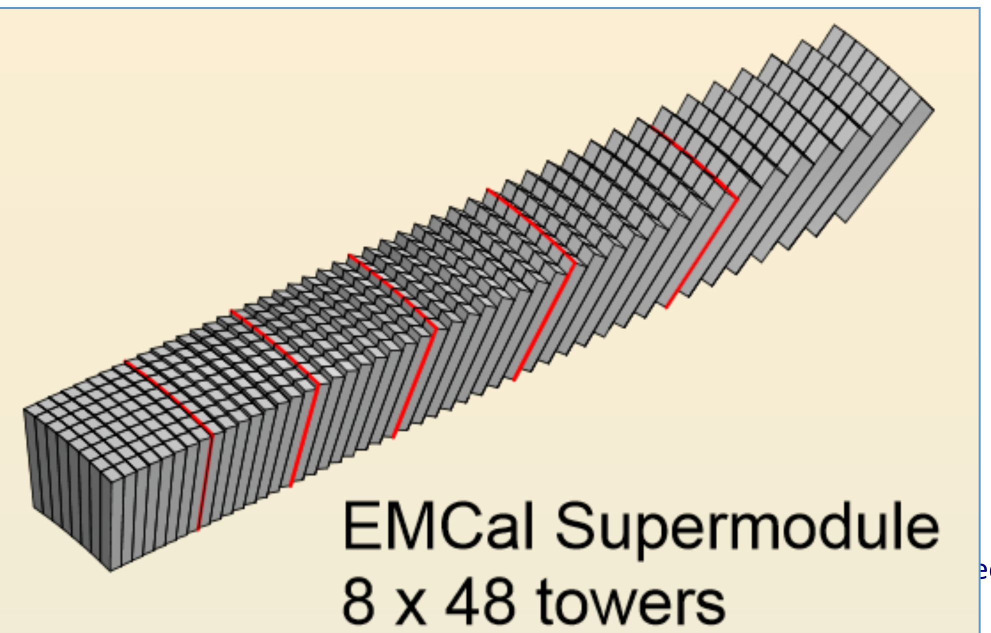
EMCal Reference Design

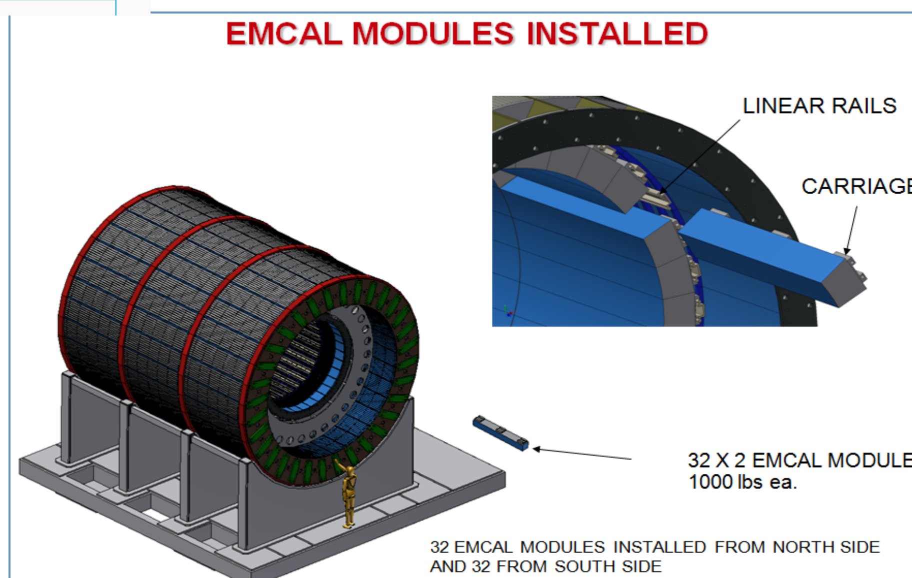


- CAD engineers working with Physics Dept personnel and university collaborators
- Efforts to produce towers of spacal modules using UCLA-developed design is ongoing at UCLA, UIUC and Tungsten Heavy Powder
- Work supported in part RHIC and EIC R&D

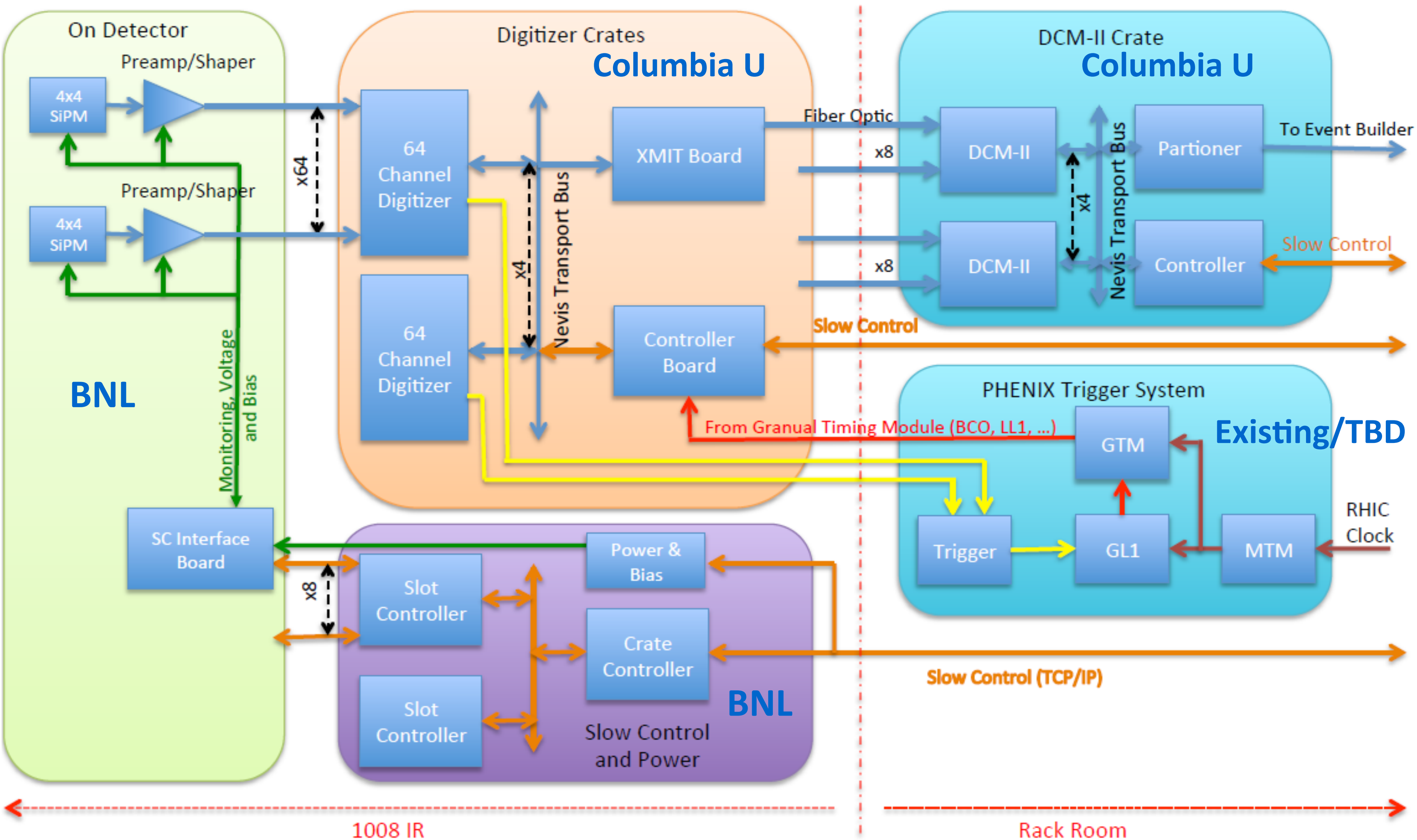
Ultimately want to build ~25k towers







Calorimeter Electronics

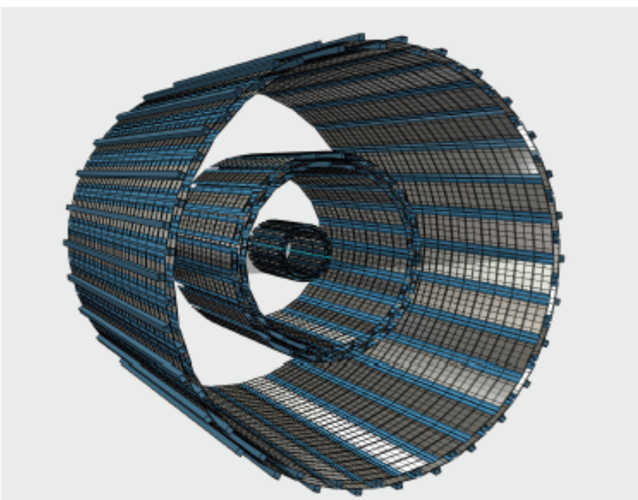


Tracker Options – Many Open Issues

All Si Tracker option

Si tracker

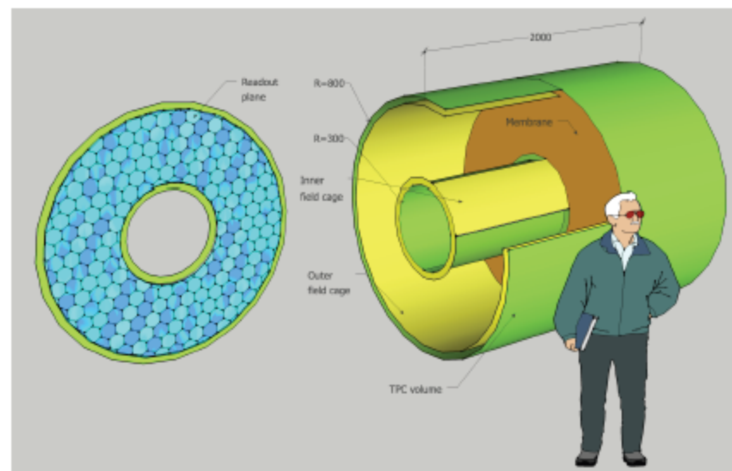
- 7 layers strips and pixels
- Achieves design goals of pattern recognition and 100 MeV mass resolution on Upsilon states
- Total thickness ≈$0.1X_0$



2 Pixel Layers + Compact TPC option

TPC + inner Si layers

- 80 cm outer radius TPC
- Inner Si detector
- TPC electronics following from ALICE upgrade



Inner pixel layers could be re-used from PHENIX VTX or MAPS pixels as in the ALICE upgrade

Major HCal Opportunities, Challenges and Tasks

- **Scintillator tile design. Grooving, tolerances, grading or patterning on surface.**
- **Qualification of scintillator vendors**
- **Design of SiPM mounting**
- **Calibration scheme**
- **Light tightening**
- **Prototyping**
- **Test beam**
- **Qualification of Module assembly locations**
- **Characterization and testing of production tiles**
- **Module assembly**
- **QA of produced modules**
- **Installation and commissioning**

Major EMCal Opportunities, Challenges and Tasks

- Manufacturing techniques for modules
- Mechanical design of the sectors
- Light collection simulation and comparison with prototypes
- Calibration scheme (LED-based is the current plan)
- Light tightening
- Prototyping
- Test Beam
- Fabrication of 25k towers
- QA of all towers
- Assembly of modules and super modules
- QA of super modules
- Installation and commissioning

Calorimeter Electronics Including SiPMs Opportunities, Challenges and Tasks

- Radiation damage characterization of SiPMs
- Monte Carlo of neutron backgrounds
- Development and testing of temperature compensation
- Gain setting
- Test pulse
- Cooling and temperature control of SiPMs. Design and implementation
- QA of 120k SiPMs

Major Tracker Opportunities, Challenges and Tasks

The Tracker is an open issue.

Both the all Si and hybrid(pixel+TPC) option have issues of:

- **Project planning and management**
- **Design**
- **Prototyping**
- **Fabrication**
- **Installation and commissioning**

Major DAQ/Trigger Challenges, Opportunities and Tasks

- **Design and production of a MB Beam-Beam type trigger device**
- **New LvL1 trigger boards.**
- **Trigger algorithm development (based on calorimeter trigger data stream)**
- **Redesign of GL1 trigger**
- **Incremental upgrades to existing DAQ. Networking, switches, etc.**

Pressing Detector Simulations Issues

- **Tracking detector(s)**
  - **Evaluate and performance for each technology choices and optimize for parameters (e.g. radius)**
  - **Realistic tracker geometry and dead map in Geant4**
  - **Detailed study and optimization for tracking efficiency, resolution and purity**
  - **Generalize Kalman filter for more complex tracker and material geometry**
  - **Alignment and alignment challenge test**
- **EM calorimeter**
  - **Refine geometry to incorporate for engineering layout in Geant4**
  - **Simulation for scintillation light production, collection and noise**
  - **Quantify the trade-offs for 2-D projectivity**
  - **Rear leakage and use if inner HCal as tail catcher**
  - **Tower-by-tower shower shape analysis**
  - **Gain variation and calibration challenge tests**
- **Hadron calorimeters**
  - **Simulation for scintillation light production and collection**
  - **Grading of tile light response**
  - **Tile tilt angle study**
  - **Detailed Magnetic field implementation and effects**
  - **Integration of EMCal, quantify leakage and resolution effect to jets and hadrons**
  - **Calibration scheme and energy scale**
  - **Simulation and analysis for the next prototype**

Physics Performance Simulations Tasks

- Standardize jet reconstruction and background subtraction
  - Standardize baseline jet reconstruction software
  - Jet resolution, leakage and unfolding
  - Finalizing particle flow jets
  - Optimization for fake jet rejections
- Heavy flavor jet tagging
  - Tracking counting performance with Geant4 and realistic detection environment
  - Secondary displaced vertex identification
  - Evaluation method for HF jet purities
- Charm and Upsilon mesons reconstruction
  - Study in full detector Geant4 simulation
  - Standardize Upsilon performance evaluation tools
- Global event properties
  - Event plane detection
  - Background subtractions
  - Primary vertex reconstruction

Summary of Areas Requiring Additional Effort

- **All detector subsystems:**
  - **Tracker (it is especially early in its design phase)**
  - **EMCal**
  - **HCal**

  There remain open design, calibration, prototyping incl beam tests, fabrication, QA, integration and commissioning issues.
- **Numerous places to contribute in both detector performance simulations and physics simulations.**
- **Places to contribute in trigger devices (Beam Beam Counters) and trigger electronics (Level1 in pp and pA)**

The Tentative Assembly Plan of Large Subsystems

- **Outer HCal** modules (6.3 m long) built at BNL
  - Need to identify space at BNL for HCal fabrication and testing.
  - University groups for prototyping, produciton QA, commissioning
- **Inner HCal** modules built at collaborating universities
  - Shipped to BNL for final testing and installation
- **EMCal** modules built in industry and assembled and tested at collaborating universities or completely built at Universities
  - Shipped to BNL for final testing and installation
- **Tracker**

  A number of options

  Inner:
  - Reconfigure existing pixels
  - Build brand new MAPs pixels based on ALICE phase 1 upgrade

  Outer:
  - Silicon built in Japan and other university and lab sites (multiple sites needed)
  - Assembly of barrel layers and testing at BNL with university groups for QA and commissioning

  OR
  - TPC components built by university and lab groups.
  - Assembly in large clean room facility TBD (BNL or university)

Participation in sPHENIX

A Lot of Ongoing Work. Meetings Open to all Who Wish To Contribute

INDICO Integrated Digital Conference

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sPHENIX

Managers: Haggerty, J.; Morrison, D.; O'Brien, E.; Lynch, D.; Mills, J.

- sPHENIX Collaboration 1 event
- sPHENIX Detector 62 events
- sPHENIX Engineering 21 events
- sPHENIX Magnet 17 events
- sPHENIX Management 42 events (protected)
- sPHENIX PMG meeting 20 events
- sPHENIX Project Status 13 events
- sPHENIX Reviews 18 events
- sPHENIX Simulations 40 events
- sPHENIX Update 2 events

Powered by Indico

Regularly Scheduled Meetings – So Far

Meeting	Time(ET)	Contact
Management(weekly)	Tues 9:30 am	Ed O'Brien
Simulations(weekly)	Tues 1:00 pm	Jin Huang
HCal(bi-weekly)	Tues 3:00 pm	John Lajoie
EMCal(bi-weekly)	Tues 3:00 pm	Anne Sickles
SC-Magnet(bi-weekly)	Wed 1:30 pm	Kin Yip
Cal Electronics(bi-weekly)	Wed 1:30 pm	Eric Mannel
Engineering(bi-weekly)	Thurs 9:00 am	Jim Mills
Prototype/Test Beam(bi-weekly)	Thurs 11:00 am	Don Lynch
L2 Manager(bi-weekly)(NEW)	Thurs 11:00 am	John Haggerty
Tracker(bi-weekly)	Fri 9:00 am	Tony Frawley
TPC R&D(bi-weekly)(NEW)	Time TBD	Takao Sakaguchi

Project Status and the November Cost and Schedule Review

Explaining DOE Project Rules

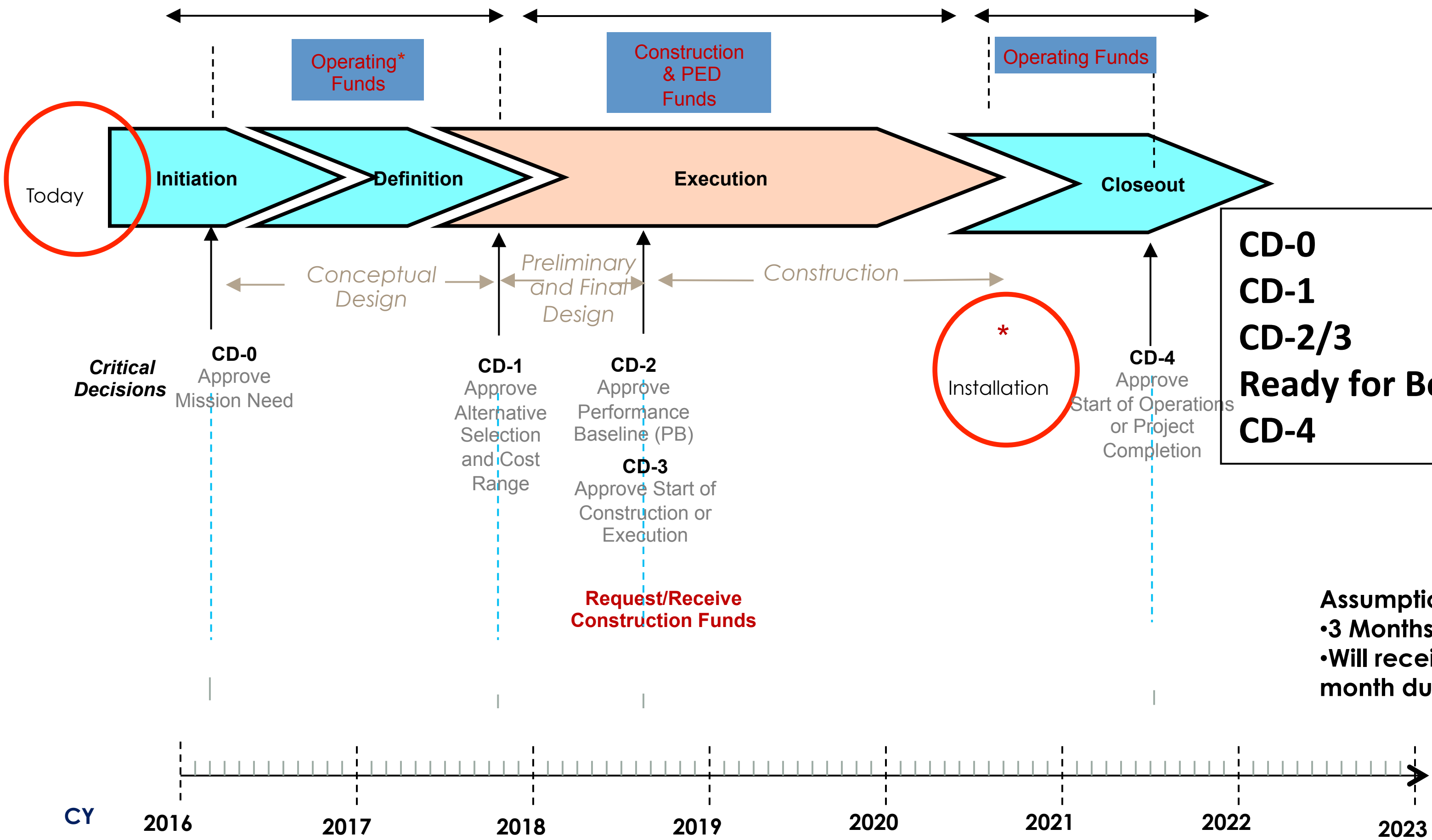
DOE has an extensive set of rules that govern how a project is to be carried out and they require all projects adhere to those rules.

- DOE has each project go through a series of Critical Decision points CD-0 through CD- 4
  - CD-0 means that DOE has determined that the project meets a mission need. Conceptual design can begin to set a cost and design with options.
  - CD-1 means that the cost range and design with option is acceptable. Preliminary design followed by final design can begin
  - CD-2 means the baseline design and cost estimate is acceptable to DOE.
  - CD-3 means that the design and R&D are complete and construction can begin
  - CD-4 means the project is complete
- sPHENIX is not yet at CD-0 but based on informal discussions with DOE we hope to get that in the spring of 2016.

At the time of CD2/3 we will be required to define a project **scope** which is a list a tangible deliverables in addition to a budget and schedule

- DOE will monitor the budget and schedule of the project on a monthly basis. More often if there are schedule and budget deviations from the plan

DOE Critical Decision Scenario



CD-0	Apr 2016
CD-1	Nov 2017
CD-2/3	Jul 2018
Ready for Beam	Jan 2022
CD-4	Jan 2023

Assumption:
- **3 Months CR**
- **Will receive 1/12 per month during CR**

- Operating Funds are used for conceptual design between CD-0 and CD-1. Operating funds may also be used prior to CD-4 for R&D, NEPA, D&D, ES&H, transition, startup, and training costs. Non-federal funds from other sources that are considered capital funds and are included in the "Total line item cost" as OPC.
- Good Practice—For the first year that TEC is requested, ensure that OPC is also requested for that year. The OPC will allow the project to continue in a long CR until TEC is available and new starts are allowed.
- MIE funds are more flexible than Line Items. Moving OPC to TEC or vice versa is much easier than for Line-Item reprogramming since MIE funds are "batched."

- New Start is defined as the first use/appropriation of any TEC funds (including TEC PED) for both line items and MIEs project.

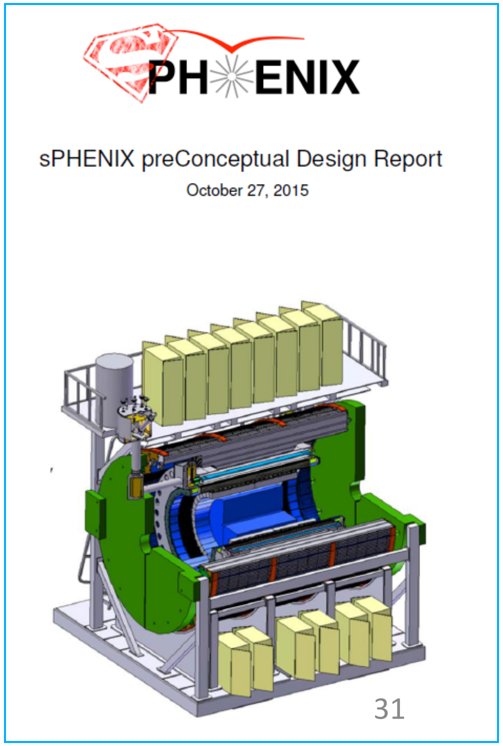
Context of the November Cost and Schedule Review

- The project is ~ 18 months from a OPA CD-1 review
- All designs are pre-conceptual
- We have chosen technologies for the reference design and that allows us to do initial schedule, resource, costing and contingency estimations
- We're in the 1st round of prototyping
- There are a number of unresolved questions and in the case of Tracker multiple options to consider.
- In the standard plan the earliest we will begin final fabrication is 4QFY18. Three years from now. However there may be early procurements of long lead time items.
- We have time before we need to make all final technology choices, but from an efficiency point of view we would like to make the decisions as soon as possible.

Documentation Created for the Review

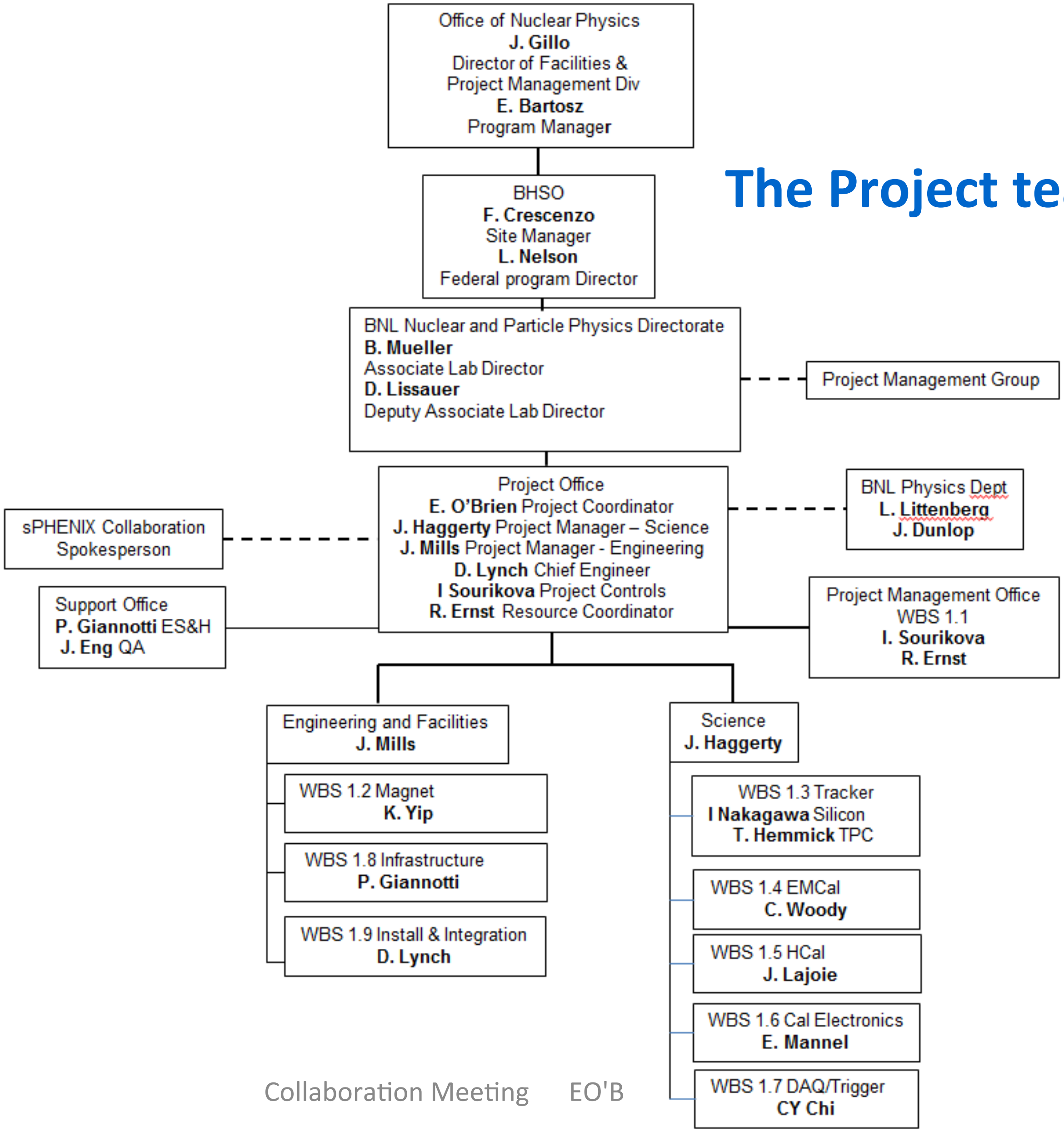
- Preliminary Conceptual Design Report
- WBS and WBS Dictionary
- sPHENIX Science Proposal to DOE plus DOE Review report
- Basis of Estimate Documents
- Preliminary Risk Analysis and Mitigation Document
- Recommendation Resolution Document
- Preliminary Safety and Hazard Analysis
- Preliminary Quality Assurance Plan

In total we produced ~1000 pages of documentation plus 36 technical or C&S presentations from 28 speakers.



Project Organization

The Project team is in place



Basis for the Project Plan

- Defined the complete Project including all components of the Total Project Cost, and key off-Project tasks like Decommissioning and the Cold Acceptance Tests of the SC-Magnet.
- Defined a WBS structure
- Assigned cognizant engineers and scientists to define all project tasks, durations, fixed(M&S) costs and labor assignments by labor category
  - **40-45 people worked on this**
  - **> 1600 tasks defined**
- Everything entered into MS-Project (no Primarvera P6 expertise on the project yet)
- Estimated all material costs through engineering estimates, discussions with vendors, previous experience.
  - **~ 80 items with material costs ≥ $50k. Wrote a Basis of Estimate form for each.**
- Assigned BNL labor rates to appropriate job categories
- Linked all tasks to create resource loaded schedule plus budget
- We also had the engineers and scientists fill out contingency estimates for each task based on material and labor risks. We have the ingredients for a bottoms-up contingency estimate, but it's not yet implemented.

Status of Project Planning

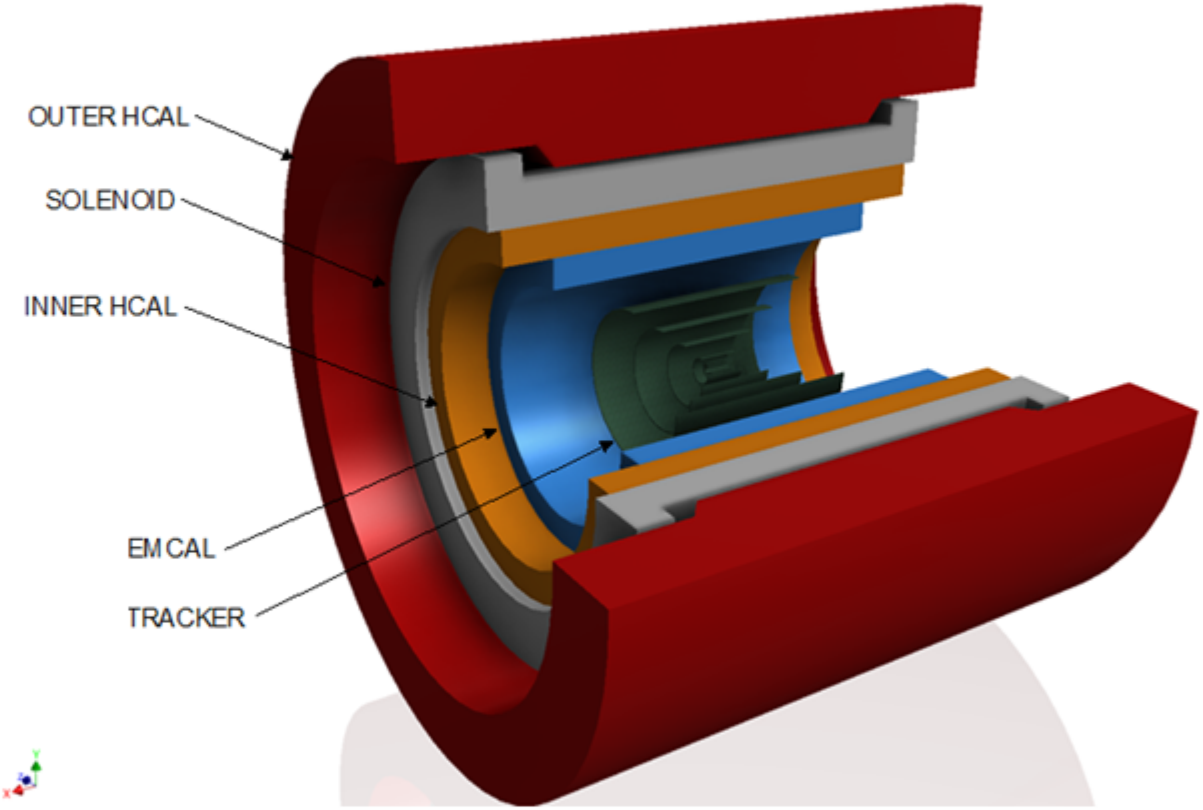
- sPHENIX resource-loaded project plan has been created to account for DOE schedule guidance, latest subsystem updates, new labor resource sheets with FY16 rates, and explicit separation between on-project (Total Project Cost) and off-project tasks.
- Input from Project Management team, L2 & L3 managers, subsystem engineers,
- >1600 tasks total. The project file is fully resource -loaded and linked (22 files total in MS-Project)
- Covers activities from now until the nominal installation of sPHENIX over 5.5 years.

Why a resource-loaded cost and schedule is important:

- Enables one to create cost profiles by year for materials and labor
- Allows you to determine when you need specific types of labor (Mech Engs or Elec Engs, techs, trades, scientists, students, etc.)
- One can run a variety of schedule scenarios depending on project approval dates, different funding profiles, etc.
- One can determine complex linkages between tasks, critical decision points for down selects, etc.
- Needed for eventual Earned Value reporting   to DOE when sPHENIX becomes a project

sPHENIX Project Scope

1.1 Project Management
1.2 SC-Magnet
1.3 Tracker *
1.4 EMCal
1.5 HCal
1.6 Calorimeter Electronics
1.7 DAQ/Trigger
1.8 Infrastructure
1.9 Installation/Integration



*** The plan is to fund the Tracker from outside sources, Japanese funding agencies, NSF and other international sources. DOE may ultimately contribute to the engineering design .**

WBS Structure

1 sPHENIX Design, Production, Commissioning
1.1 Project Management
1.2 Magnet
1.3 Tracker
1.4 EMCal
1.5 HCal
1.6 Calorimeter Electronics
1.7 DAQ/Trigger
1.8 Infrastructure
1.9 Installation/Integration
2 sPHENIX Preconceptual Activities
2.1 Decommissioning
2.2 Magnet Acceptance Testing
2.3 Tracker Generic R&D and Preconceptual Design
2.4 EMCal Generic R&D and Preconceptual Design
2.5 HCal Generic R&D and Preconceptual Design
2.6 Calorimeter Electronics R&D and Preconceptual Design
2.7 DAQ/Trigger generic R&D and Preconceptual Design
2.8 Infrastructure Preconceptual
2.9 Installation and Integration Preconceptual

The WBS structure has a few advantages:
- Natural separation of on-project and off-project costs and resources
- Allows one to balance resources and link tasks between on-project and off-project WBS elements
- No major changes to WBS structure once we get CD-1

Summary of Review Recommendations

- **Now with DOE and BNL permission make the 1-year stretch schedule the default plan.**
  - sPHENIX commissioned and ready for beam Jan 2022
- Increase your contingency for this stage of the project, at least until there exists a bottoms-up contingency estimate. Reduce technical, schedule and budget risk by advancing and simplifying designs, performing R&D, solidifying quote with vendors. Reduced risk = reduced contingency
- Plan the Tracker as if it is part of the Project, not just a non-DOE deliverable. Vigorously pursue alternate funding for this device.

These two recommendations taken together imply a potential project cost 25-30% higher than what we presented at the review if no outside funds are available and the contingency remains high.

- Recommend reuse of existing pixel layers from PHENIX VTX to sPHENIX
- Scrub the project budget and incorporate resources from other US and international institutions. Pursue funding from non-DOE sources and contributions in kind from collaborating institutions.

Project – Collaboration Organization

The sPHENIX by-laws specify that the Project Director will inform the sPHENIX EC of the project status at the monthly EC.

BNL Nuclear and Particle Physics Directorate
B. Mueller
Associate Lab Director
D. Lissauer
Deputy Associate Lab Director

Project Management Group

sPHENIX Collaboration Spokesperson

Project Office
E. O'Brien Project Coordinator
J. Haggerty Project Manager – Science
J. Mills Project Manager - Engineering
D. Lynch Chief Engineer
I Sourikova Project Controls
R. Ernst Resource Coordinator

BNL Physics Dept
L. Littenberg
J. Dunlop

Support Office
P. Giannotti ES&H
J. Eng QA

Project Management Office
WBS 1.1
I. Sourikova
R. Ernst

Engineering and Facilities
J. Mills

- WBS 1.2 Magnet — **K. Yip**
- WBS 1.8 Infrastructure — **P. Giannotti**
- WBS 1.9 Install & Integration — **D. Lynch**

Science
J. Haggerty

- WBS 1.3 Tracker — **I Nakagawa** Silicon, **T. Hemmick** TPC
- WBS 1.4 EMCal — **C. Woody**
- WBS 1.5 HCal — **J. Lajoie**
- WBS 1.6 Cal Electronics — **E. Mannel**
- WBS 1.7 DAQ/Trigger — **CY Chi**

I'd like to propose an additional Project - Collaboration forum
A Joint Liaison Committee:
Project Director + one deputy &
Spokesperson + one deputy &
Rep from Berndt's office
A bi-weekly meeting of such a group would be beneficial

Issues and Concerns

- The recent review concluded that the **potential** cost of the project to DOE was 25-30% higher than the project had estimated if no outside funding could be secured and technical uncertainty remained high.
- There are a number of open technical questions (typical for pre CD-0):
  - Tracker technology choice
  - EMCal 1-D or 2-D projective
  - Stand alone cryo for magnet or integration with RHIC cryo.
- The Project Construction time is short between anticipated CD2/3 date and start of RHIC run in 2022. Even with the stretch of the schedule one year to Jan 2022, an efficient procurement start will be important.
- Tracker is planned to be funded from non-DOE sources (Si from JSPS, TPC from NSF and others). Discussions have started but nothing is set.
- The technically driven funding profile is steep. Need to find ways to smooth.
- Labor needs have been estimated, but not all resources are identified. A one year schedule stretch helps the need for techs in FY19-20 by stretching over three years instead of two. However this has an impact on re-directs.

Summary - 1

- A Project Team has been established to carry out the sPHENIX project
- Preconceptual design and generic R&D is ongoing. A great deal of progress has been made.
- A resource-loaded project plan exists (in MS-Project) that is being used to plan the schedule, budget and resources for the project
- Preliminary Project documentation exists
- The Tracker is will be planned along with other activities in the resource-loaded plan
- A “1 year stretch” schedule with a completion in Jan 2022 will need to be detailed to become a fully resource-loaded Project plan. The stretch schedule solves the labor bump and gives the project ~7 month float, but needs further development.

Summary - 2

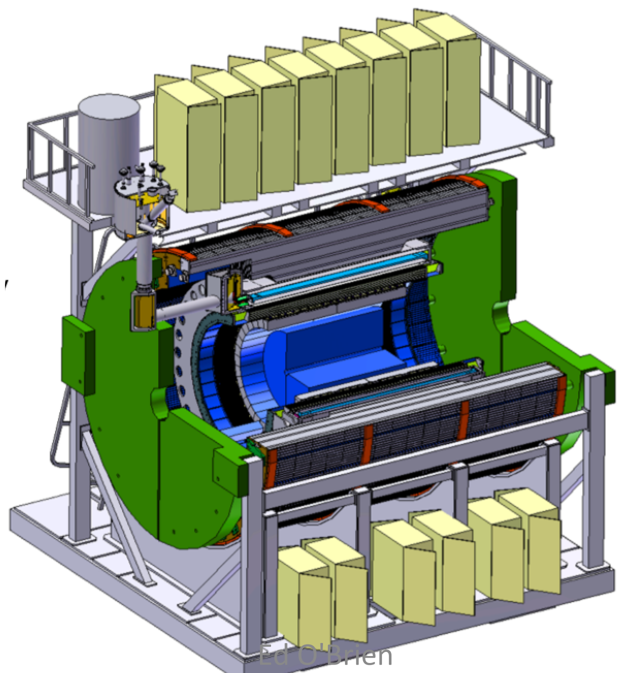
- **We need to find creative and effective ways to reduce cost, reduce technical risk and speed the schedule.**
- **This can be done, but we need more people working and contributing.**
- **We have a great opportunity right now to make that happen. Experienced people will tell you that this type of opportunity doesn't come around very often.**
- **We've built a strong team at BNL, with Lab backing, and are accreting a number of outside institutions. But we need many more…..**
- **There are many ways for you to contribute. We need your help.**

Back Up

‘ sPHENIX

is

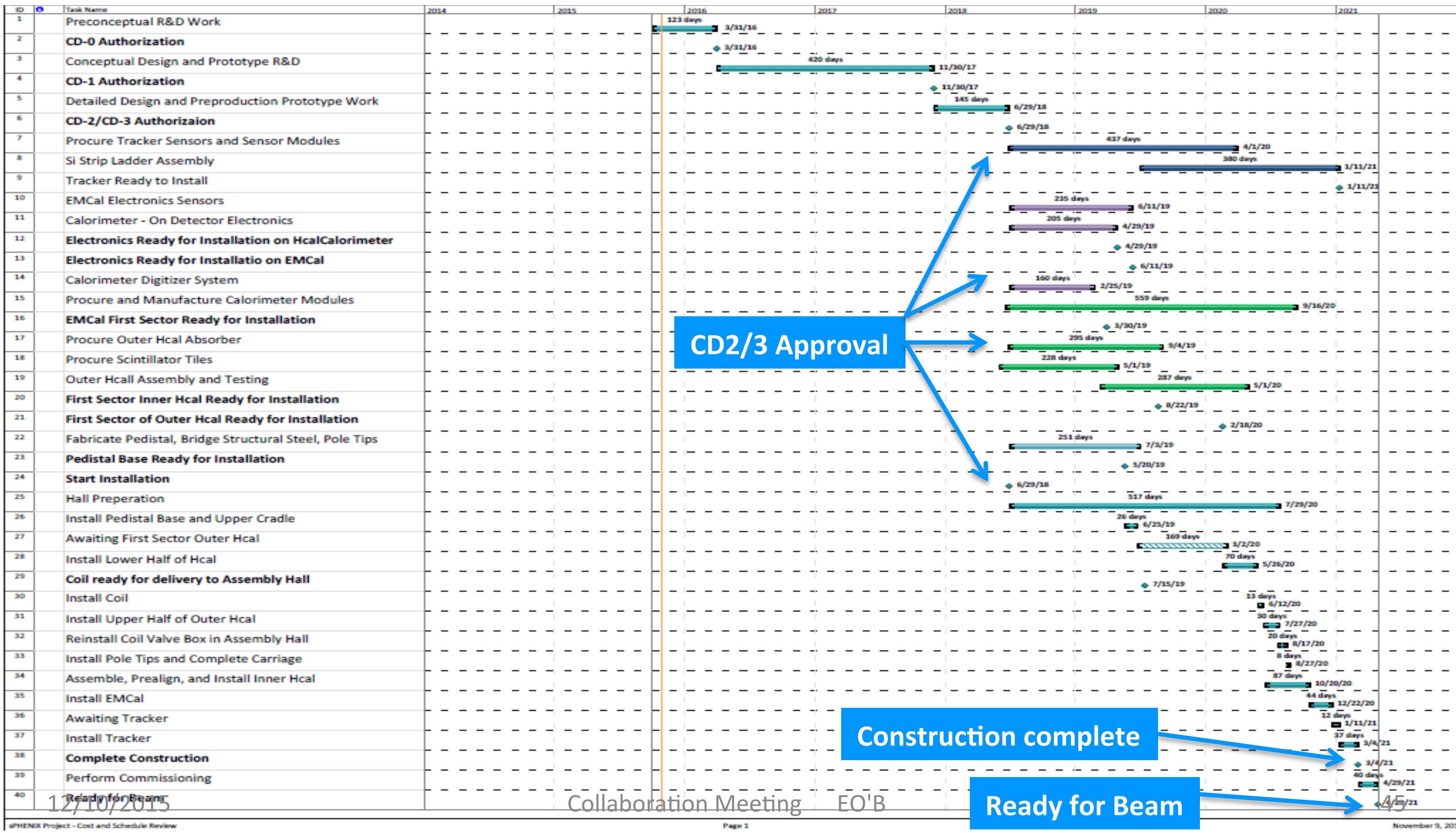
‘sWonderful



An Experiment Name in the Tradition of D0 and L3

sPHENIX Schedule

Initial schedule shows Installation complete **Mar 1 2021**. Commissioning complete **Apr 29, 2021**.
Based on authorization for CD-1 Nov 2017, CD-2/3 Jul 2018.
Two approaches to address the tight schedule:
1) CD-3a in Nov 2017 for long lead time items. 2) One year stretch in the schedule



Cost and Schedule Review Committee

sPHENIX Cost and Schedule ALD Status Review
November 9-10, 2015
Brookhaven National Laboratory
Review Committee
(* = subcommittee chair)

Jon Kotcher, Chair

Project Management

Dmitri Denisov - Fermilab
John Hobbs – Stony Brook*

Cost and Schedule

Bill Freeman - Fermilab
Xiaofeng Guo – BNL*
Penka Novakova – BNL

Magnet, Installation, Integration and Decommissioning

George Ganetis - BNL
George Ginther - Fermilab
Phil Pile – BNL*

Calorimetry

Michael Begel – BNL*
Hong Ma – BNL
Mike Tuts – Columbia

Tracking

Graham Smith – BNL*
Gerritt Van Nieuwenhuizen – BNL

Electronics/Trigger/DAQ

Chris Bee – Stony Brook*
Hucheng Chen -- BNL